AD-A054 291 LOCKHEED MISSILES AND SPACE CO INC PALO ALTO CALIF PA--ETC F/G 17/5
EFFECTS OF GAMMA IRRADIATION ON SURFACE PROPERTIES AND DETECTOR--ETC(U).
MAR 76 F A JUNGA, W W ANDERSON, R B EMMONS F19628-75-C-0127

UNCLASSIFIED LMSC/D623269 RADC/ETR-78-0055 NL

| OF |

AD
A054291

END
DATE
FILMED
6-78
DDC

ETR 78 0055

AD A054291

AD No.
DDC FILE COPY

DDC
RECEIVED
MAY 17 1978
D

EFFECTS OF GAMMA IRRADIATION ON SURFACE PROPERTIES AND DETECTOR PROPERTIES OF $Hg_{1-x}Cd_xTe$ PHOTOCONDUCTORS*

F. A. Junga, W. W. Anderson, and R. B. Emmons
Lockheed Palo Alto Research Laboratory
Palo Alto, California 94304

At low optical backgrounds and sufficiently low temperature, some $Hg_{1-x}Cd_xTe$ photoconductive detectors exhibit minority carrier "trapping" effects. While these trapping effects are important to device performance the source of trapping has not been identified. Attempts to model this phenomenon using a distribution of bulk trapping states have resulted in predictions which are inconsistent with experimental observations. However, it has been suggested that the detector surface plays an important role in the trapping process. This suggestion is reinforced by the experience of detector manufacturers who find that detector properties are dependent on device surface treatment. In this paper we will present some of the results of a program whose purpose was to determine the role of the surface on detector properties and the effects of ionizing radiation on surface properties and detector performance.

The test devices used in this study consisted of an MIS structure and a photoconductor fabricated on the same die. With this combination of test devices both detector properties and surface properties could be compared before and after irradiation. The MIS structure had a ZnS insulating layer and a semitransparent Au top electrode. Thus, the MIS structure was photosensitive. One-half of the photodetector was also ZnS coated. The coated and uncoated sections of the detector could be tested separately. The front and back surfaces of the photo MIS device and the detectors received the same chemical treatment. Devices were fabricated from wafers of appropriate composition to produce energy gaps of 0.3 eV and 0.1 eV at 80°K.

The responsivity and noise as a function of temperature were measured on each of the three detectors on each die. The measurement techniques were quite standard and will not be discussed. The responsivity of the photo MIS detectors could also be measured as a function of V_g and hence surface potential, to determine the effects of surface potential on minority carrier lifetime.

These studies showed that all detectors had qualitatively the same general characteristics, with no systematic variations due to surface configuration. The photoconductive lifetimes were in the range of 1-3.5 msec and the quantum efficiencies were in the range of 0.02 to 0.2. The frequency dependence of responsivity in all detectors showed the usual, slower than 1/f roll off. All detectors were excess noise limited at the backgrounds used. The photoconductive lifetimes

*This work was supported in part by the Deputy for Electronics Technology, Air Force Systems Command, Bedford, Mass. under Contract No. F19628-75-C-0127.

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

in both compositions are dependent on surface potential and have broad peaks near midgap. The departures from this maximum value, however are not large.

The capacitance vs. voltage (C-V) characteristics of the MIS structures were used to characterize the surface of the detectors. Surface state density distributions were extracted from the low frequency ($f \geq 5$ Hz) data. C-V measurements on the 0.3 eV gap devices ($T = 80°K$) showed that unbiased surface was depleted ($\psi_s = -0.125$ eV). However, measurements on the 0.1 eV gap device ($T = 8°K$) showed that the unbiased surface was inverted ($\psi_s = -0.095$ eV).

Surface state density distributions in detectors of both alloy compositions were found to peak at or near the band edges. The peak near the valence band edge consisted of donor-like states while the peak near the conduction band edge contained acceptor-like states. The peak densities in both compositions were in the range of 1 to 2×10^{12} cm^{-2} eV^{-1}.

The devices were gamma irradiated to a dose of 2×10^5 rad (Si) at 80°K and maintained at that temperature until both detector properties data and C-V data were obtained. Irradiations were performed with various MIS gate biases. The gate bias had no effect on the outcome of the irradiations. Irradiation of detectors of both compositions resulted in an increase in the density of donor-like surface states at the valence band edge. The responsivity and noise of the wider gap detectors increased significantly upon irradiation while the responsivity of the narrow gap devices decreased only slightly and the noise was unchanged. The surface potential after irradiation was essentially unchanged in both composition detectors. These results, or at least the effect of irradiation on responsivity, are important since they argue against a surface state dominated trapping mechanism. We note that in the wider gap detector the pre and post irradiation surface potential resided at about -0.125 eV below the conduction band, that is in the region where irradiation had no dramatic effect on surface state density. However, the responsivity increased significantly after irradiation. Likewise, the surface potential in the narrower gap device was unchanged after irradiation and remained at the valence band edge. The surface state density at the valence band edge increased significantly. Now, however, we see almost no change in responsivity. Thus, on the one hand we have a large change in responsivity after irradiation in the detector in which the Fermi energy resides in a region of unperturbed surface state density while in the detector in which the Fermi energy resides near a maximum in the surface state density, which is increased further by irradiation, the responsivity is unchanged by irradiation. These two results strongly suggest that surface states do not play a part in the minority carrier trapping process. These data, however, are not inconsistent with a trapping model which employs a single bulk state, in conjunction with a depleted surface to account for the characteristics of trapping detectors. This model will be discussed in light of the results of this program.

In summary we have found that ionizing radiation effects depend on energy gap but not on surface potential. In addition the radiation effects suggest that trapping behavior is not associated with surface states.

ACCESSION for
NTIS White Section ☒
DDC Buff Section ☐
UNANNOUNCED ☐
JUSTIFICATION..........................

BY..........................
DISTRIBUTION/AVAILABILITY CODES

Dist.	AVAIL. and/or SPECIAL	
A		

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

18 19 **REPORT DOCUMENTATION PAGE**

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER RADC ETR-78-0055	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) 6 EFFECTS OF GAMMA IRRADIATION ON SURFACE PROPERTIES AND DETECTOR PROPERTIES OF $Hg_{1-x}Cd_xTe$ PHOTOCONDUCTORS (sub 1-x Cd sub x Te)		5. TYPE OF REPORT & PERIOD COVERED Abstract of presentation at IEEE RAD Effects Conf.
		6. PERFORMING ORG. REPORT NUMBER 14 LMSC/D623269
7. AUTHOR(s) 10 F. A. Junga, W. W. Anderson, R. B. Emmons		8. CONTRACT OR GRANT NUMBER(s) 15 F19628-75-C-0127 New
9. PERFORMING ORGANIZATION NAME AND ADDRESS Lockheed Palo Alto Research Laboratory 3251 Hanover Street Palo Alto, CA 94304		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62702F 61102F 16 2306J324 17 J3
11. CONTROLLING OFFICE NAME AND ADDRESS Defense Nuclear Agency Washington, D.C. 20305		12. REPORT DATE 11 March 1978
		13. NUMBER OF PAGES 3
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Deputy for Electronic Technology (RADC) Hanscom AFB, Massachusetts 01731 Monitor/J. Silverman/ESE 12 5p.		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Paper to be presented at the 1978 IEEE Conference on Nuclear & Space Radiation Effects, Sponsored by IEEE, at Albuquerque, New Mexico July 18-21, 1978.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

INFRARED DETECTORS, MERCURY-CADMIUM TELLURIDE, IONIZING RADIATION EFFECTS, SURFACE STATE STUDIES

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The effects of surface potential and surface states on the properties of and radiation sensitivity of trapping mode mercury cadmium telluride detectors with energy gaps of 0.3 eV and 0.1 eV were investigated. These studies were made with photo MIS structures. Low frequency C-V measurements were made and a program developed to extract the surface state density and surface potential from these data. The responsivity of these devices was dependent on surface potential. Gamma irradiation increased the number of surface states at the (over)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

210118

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

valence band edge but did not affect surface potential. The 0.3 eV detectors appeared to be more radiation sensitive than the 0.1 eV detectors.

The results of this study are briefly discussed in light of current models for trapping behavior.